# Lidar Mapping for Transportation Corridors

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Light Detection and Ranging (LiDAR) Technology Evaluation project was undertaken to provide an analysis on the current state of Laser based technology and its applicability, potential accuracies and information content with respect to MoDOT applications.

This study involved collection of Airborne, Static (Terrestrial) and Mobile LiDAR over a known project area with existing control and check data sets and provides an assessment of accuracy, cost and feasibility for MODOT projects.

Sanborn Map Company
HDR Engineering
Missouri Department of Transportation

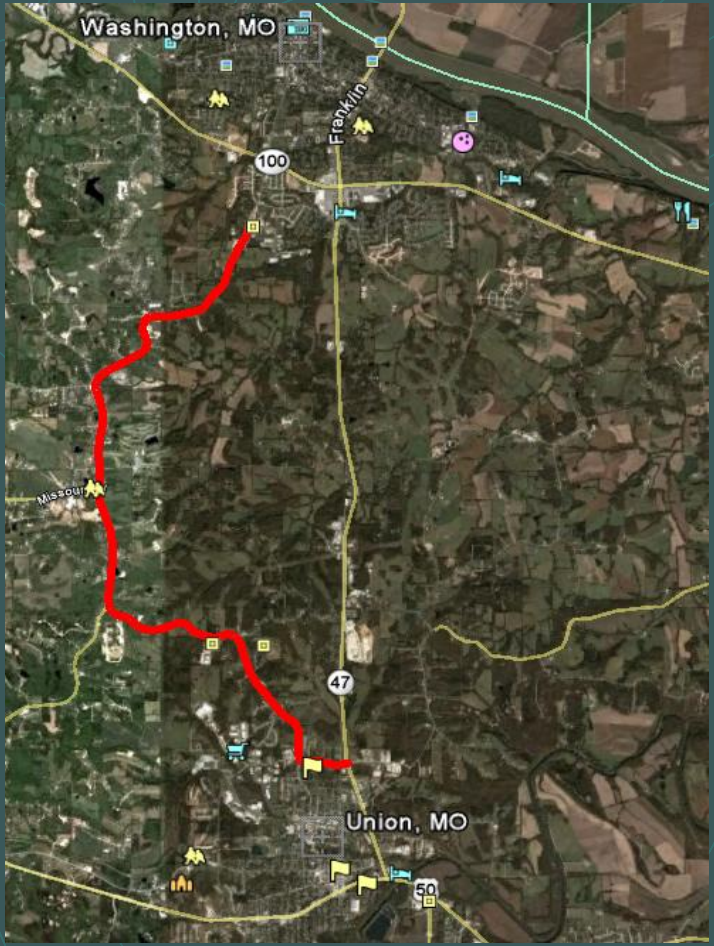
# Goal of Research

- Evaluate Advantages (or disadvantages) of data collected from LiDAR based mapping technology compared with data collected from traditional photogrammetric and survey methods.

# Goal of Research

- A 7.5 mile relocation project was selected for study by MoDOT where data was collected by standard photogrammetric processes
- Study would perform:
  - Aerial Lidar
  - Mobile Lidar
  - Static Lidar
- Compare to traditional ground survey also

# Project Location




- The data collection for this research was undertaken along Route A in Franklin County, Missouri between the cities of Union and Washington.
- This area was chosen due to the availability of independent survey control and reference data

# Data Collection

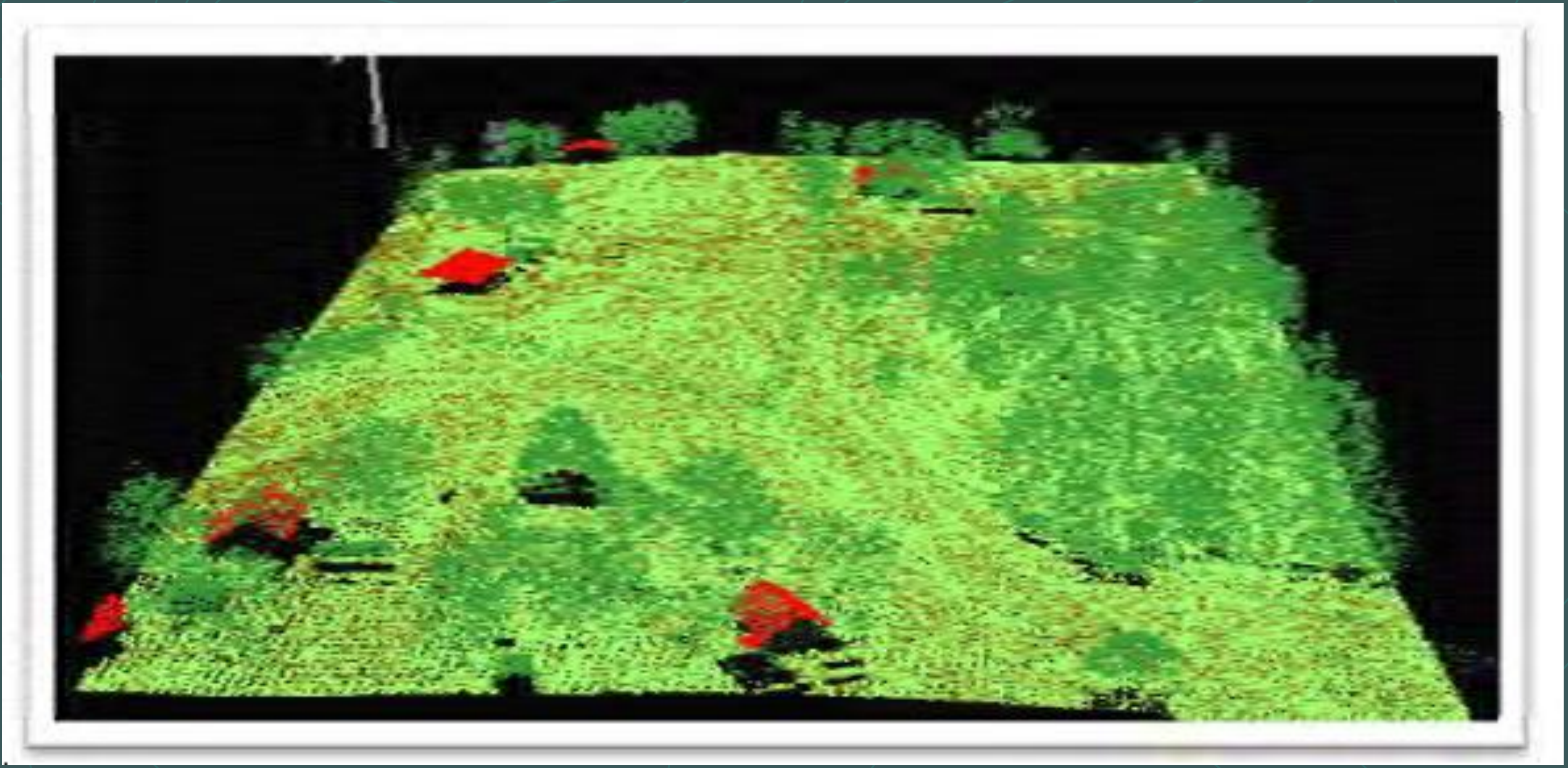
- Aerial Data was collected December 17, 2009
- Mobile data was collected December 17 with a test run on December 16 to review the route for any potential collection issues
- The static collection occurred December 17th and December 18, 2009.

# Aerial Collection


Aerial LiDAR System Leica ALS50-II


Aerial Digital Camera Appanix DSS 439

# Aerial Collection

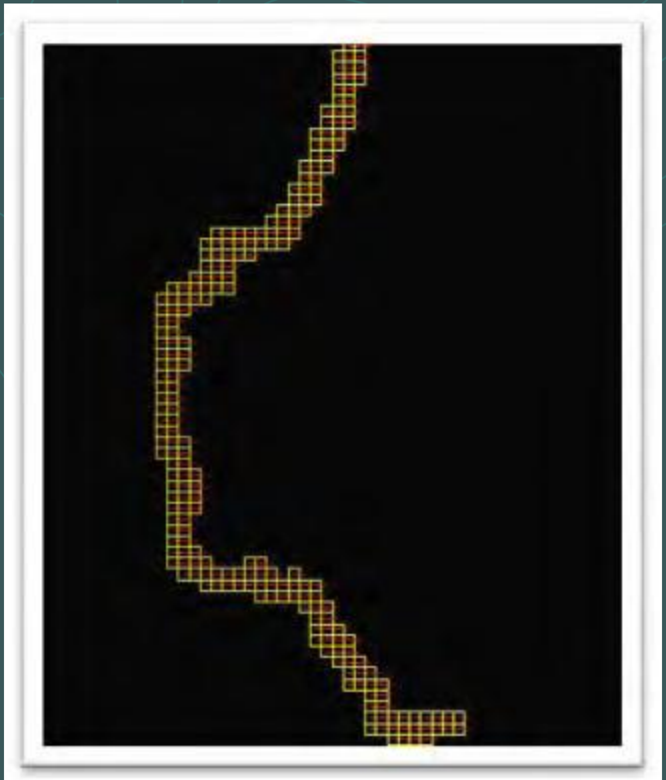


Classified Laser (Front View) Ground, Buildings, Vegetation

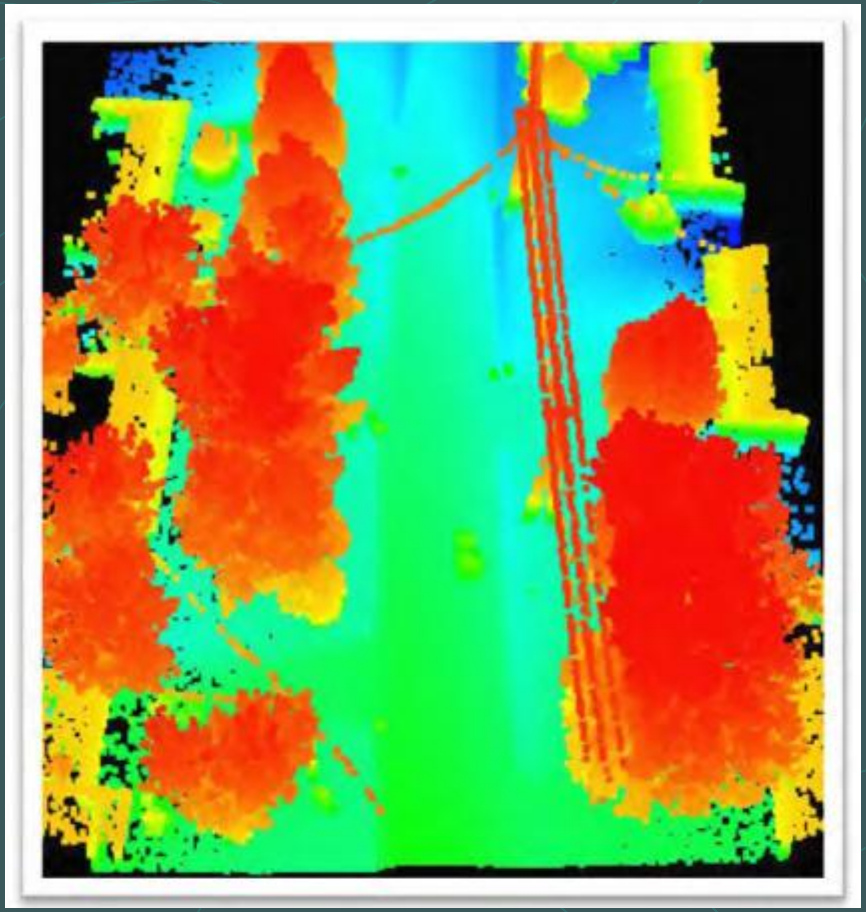
# Mobile Collection


Optech Lynx Mobile Mapping System

# Mobile Collection



Mobile Tile Scheme



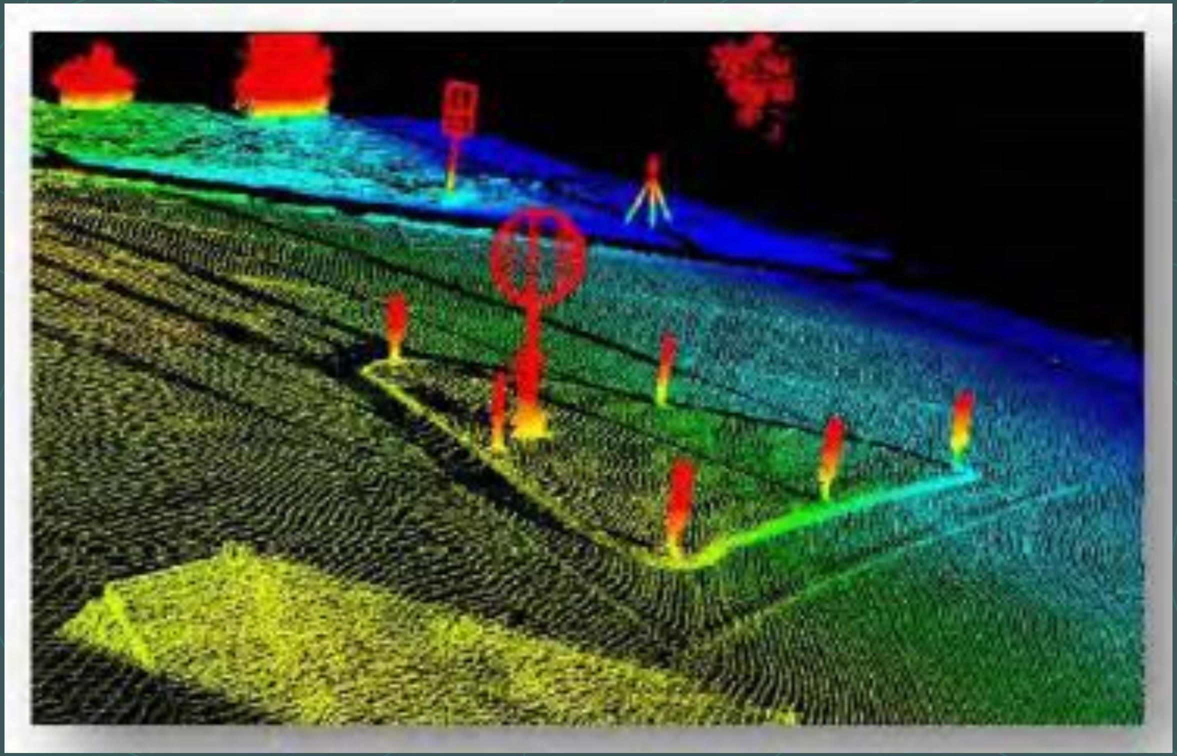
Mobile Data - All Points

# Static Collection


Optech ILRIS 3D Laser Scanner

Trimble GX Advanced Terrestrial Scanner

# Static Collection



Static LiDAR Intersection Route A and Highway BB Colored by Elevation

# Feature Extraction

- Stereo collection using LiDAR- Grammetry was utilized for breakline and feature extraction

# Feature Extraction

- Synthetic “black & white” Stereo Imagery was generated from both the mobile data and aerial datasets using GEOCUE LiDAR1 Cue PAC for use in feature mapping in 3D stereo environment. The stereo imagery was created using all point classes to create 3D datasets comprising all the required features.

# Project Overview

- Key Observations
  - Aerial Lidar –
    - Collect  day or night –schedule flexibility
    - Can “map” the same features as traditional photogrammetry” – look down perspective
    - Cost effective for wide area projects
    - Provide higher density “3D point” measurements to improve surface modeling
    - Requires additional specialized software and hardware

# Project Overview

- Key Observations
  - Mobile Lidar–
    - Collect  day or night –schedule flexibility
    - Map many similar features as photogrammetry, however is limited due to ground perspective
    - Suitable for corridor, urban or tunnel mapping
    - Provide significantly higher density “point” measurements to improve surface modeling
    - Lower risk and rapid collection of data over conventional survey
    - Limitations as to the range of the sensor and occlusions or shadowing affecting potential information content
    - Requires additional specialized software and hardware

# Project Overview

- Key Observations
  - Static Lidar
    - Collect  day or night
    - Map a limited feature set as compared to photogrammetry
    - Suitable for high detail local area surveys, such as tunnels, or enhancement project
    - Provide highest potential short range density “point” measurements to improve surface modeling
    - Reduces risk and potential schedule over traditional survey
    - Requires additional specialized software and hardware

# Data Volume

- LiDAR Technology collects an enormous volume of data, depending on the application this may not be required

| Class | Points |
|---|---|
| Default | 39,871 |
| Ground | 30,815,366 |
| Low Vegetation | 57,778,875 |
| Medium Vegetation | 2,680,066 |
| High Vegetation | 18,064,128 |
| Buildings | 3,105,888 |
| Low Points | 5,266 |
| | |
| Total | 112,489,460 |

Aerial LiDAR

| Class | Points |
|---|---|
| Default | 12,930,697 |
| Ground | 88,843,333 |
| Low Vegetation | 429,024,011 |
| Medium Vegetation | 24,694,914 |
| High Vegetation | 101,940,979 |
| Buildings | 1,018,456 |
| Low Points | 14,308 |
| | |
| Total | 658,466,698 |

Mobile LiDAR

# Cost Summary

| Summary | Hrs | Labor Cost | Person Days | $/Mile |
|---|---|---|---|---|
| Traditional Survey Design | 1281 | $131,585 | 160.1 | $18,798 |
| Aerial Lidar | 444 | $58,250 | 55.5 | $8,321 |
| Mobile Lidar | 726 | $81,688 | 90.8 | $9,933 |
| Static Lidar | 1700 | $204,805 | 212.5 | $29,258 |
| Conventional Aerial Mapping | 548 | $55,234 | 68.5 | $7,891 |
| | | | | |

****Cost Estimated on 7 Mile corridor - Mobilization cost and ODC's not included

- Conventional Aerial is still the most cost effective method to collect traditional mapping features
- Lidar can provide potential cost saving over traditional survey providing additional information content that can be "mined" in the office

# Schedule Summary

| Summary | Person Hrs | Schedule |
|---|---|---|
| Traditional Survey Design | 1281 | 48.2 |
| Aerial Lidar | 444 | 40.5 |
| Mobile Lidar | 726 | 57.1 |
| Static Lidar | 1700 | 94.0 |
| Conventional Aerial Mapping | 548 | 42.9 |
| ****Schedule is based on staff | | |

- Conventional Aerial or LiDAR Mapping provides for the shortest potential schedule for mapping data, based on available staff and resources
- Aerial and Mobile Lidar can provide schedule benefit over traditional survey methods

# Potential Safety Impacts

| TASK | Aerial LiDAR | Comments | Mobile LiDAR | Comments |
|---|---|---|---|---|
| Planning | Low | Office | Low | Office |
| Ground Survey- base Stations | Low | Remote or controlled location | Low | Remote or Controlled Location |
| Ground Survey –Control | Med | Check point collection | Med | 1 or 2 survey points/mile |
| Data Collection | NA | Low- Aerial | Low | Collected in traffic |
| Traffic Control | NA | NA- Aerial | NA | Collected at posted speed |
| Road Access | NA | NA- Aerial | Low | Collect on any accessible road/track/trail |

Aerial and Mobile Lidar reduces the need for surveyors on or near the road

# Potential Safety Impacts

| TASK | Conventional Aerial | Comments |
|---|---|---|
| Planning | Low | Office |
| Ground Survey- base Stations | Low | Remote or controlled location |
| Ground Survey –Control | Med | Check point collection |
| Data Collection | NA | Low- Aerial |
| Traffic Control | NA | NA- Aerial |
| Road Access | NA | NA- Aerial |

- Traditional Aerial is a low risk activity as the primary data collection is remote

# Potential Safety Impacts

| TASK | Static LiDAR | Comments | Traditional Survey | Comments |
|---|---|---|---|---|
| Planning | Low | Office | Low | Office |
| Ground Survey- base Stations | Med | Near project – road area | Med | Near Road Project |
| Ground Survey –Control | High | Near project – road area | High | Near project – road area |
| Data Collection | High | Edge of road /on road | High | Edge of road /on road |
| Traffic Control | High | Required for safety- shoulder/lane closures | High | Required for safety- shoulder/lane closures |
| Road Access | High | Speed and cone zones | High | Speed and cone zones |

- Traditional and Static survey have a higher degree of risk and impact as these activities are on or near the roadway

# Additional Features from LiDAR

| Feature | Aerial LiDAR | Mobile LiDAR | Static LiDAR | Traditonal Aerial |
|---|---|---|---|---|
| Curb | Restricted | YES | YES | YES |
| Gutter/Drain | Yes | YES | YES | YES |
| Traffic signal | NO | YES | YES | NO |
| Traffic poles | NO | YES | YES | YES |
| Road and Local Terrain Information | YES | YES | YES | YES |
| Parking Meters | NO | YES | YES | NO |
| Walls | YES | YES | YES | YES |
| Obstruction in the right of way | YES | YES | YES | Restricted |
| Manholes | NO | YES | YES | YES |
| Sidewalks | YES | YES | YES | YES |
| Overhead Clearance | NO | YES | YES | NO |
| Lights | Restricted | YES | YES | Restricted |
| Utility Wires and Connections | Restricted | YES | YES | Restricted |
| Garbage Cans | NO | YES | YES | NO |
| Benches | NO | YES | YES | NO |
| Fences | NO | YES | YES | Restricted |
| Guardrails/Barriers | NO | YES | YES | YES |
| Retaining Walls | Restricted | YES | YES | YES |
| Vegetation -Line of Site obstructions | Restricted | YES | YES | Restricted |

- Many of the Lidar based Features can be captured via “virtual survey “ in the office – reducing field costs

# Implementation Benefits

- **Safety enhancements**
  - LiDAR surveying techniques can provide a safer method of surveying a project corridor.
  - Surveyors, motorists, and designers all will see an improvement in safety throughout the project corridor, during surveying operations and through the reduction in site visits and design field checks.

# Implementation Benefits

## Accuracy

- The accuracy and detail of the LiDAR survey allows for increased efficiency in the design phase of the project.

| | | MOBILE DATA | | Aerial Data | |
|---|---|---|---|---|---|
| | | US Feet | cm | US Feet | cm |
| **Average dz** | | -0.002 | +0.06 | -0.019 | -0.57 |
| **Minimum dz** | | -0.196 | -5.97 | -0.472 | -14.39 |
| **Maximum dz** | | +0.338 | +10.3 | +0.318 | +9.69 |
| **Average magnitude** | | +0.104 | +3.17 | +0.135 | +4.11 |
| **Root mean square** | | +0.0126 | +3.84 | +0.173 | +5.27 |
| **Std deviation** | | +0.128 | +3.90 | +0.173 | +5.27 |

- The LiDAR survey allows for more accurate development of project profiles and for generation of more precise earthwork quantities.
- The LiDAR data can be filtered from a highly, detailed survey  to a lower data density tailored to meet specific project needs.

# Implementation Benefits

- **Speed**
  - The speed of collection, especially mobile LiDAR, cannot be matched via traditional methods.
  - The enhancement in speed of collection allows surveying tasks to be completed around constraints that restrict when certain activities may take place.

# Implementation Benefits

- **Cost**
  - LiDAR surveys can help reduce construction change orders in earthwork quantities by providing a more accurate existing ground model.
  - They can help to limit costs associated with design tasks by allowing existing sign surveys to be conducted from the office and assist in utility coordination by providing overhead clearances without having to conduct a separate field visit.
  - The reduction of field work also saves user costs associated with traffic control and lane drops that are required to safely conduct field operations.

# Project Recommendations

- MoDOT should consider the following:
  - Develop leaders in the area of LiDAR collection techniques through specialized training and workshops.
  - Develop procedures and deliverable standards for working with LiDAR survey data sets.
  - Upgrade and maintain currency with software and hardware requirements
  - Seek out additional opportunities to implement LiDAR surveying techniques on projects, while understanding that LiDAR may not be best suited for all surveying needs.

# Project Conclusions

- Technology Limitations
  - All three technologies collect enormous amounts of point cloud data that proved extremely difficult to process and manage.
  - Current software is limited in dealing with the mobile dataset in particular, requiring additional file creation and data management challenges.
  - The mobile technology significantly reduces field collection time but increases back office processing, requiring potentially additional hardware and software to effectively manage the datasets.

# Project Conclusions

- Lidar can provide schedule savings over traditional survey
- One important issue in selecting a LiDAR technique is to evaluate the future multiple potential uses of the data.
- LiDAR collection is a potential tool that can be used and designers and project managers should consider it, even when the cost savings may be realized on a future project
- While not the best solution for all surveying needs, LiDAR surveys do provide benefits to the end user in terms of data and to the public in terms of reduction in traffic disruption during  field work.

# What is MoDOT doing with this Technology?

# MoDOT’s Lidar Efforts

- MoDOT’s Design Division has been heavily involved in evaluating the potential uses of LiDAR technologies for the past 3 years.

  As a result of that research along with the recommendations of this research report, MoDOT has taken a number of steps to implement this technology

# MoDOT's Lidar Efforts

- MoDOT has purchased two static LIDAR scanners for evaluation in real-world project use. One scanner is located in our Springfield District and one is located in our Kansas City District. These units are from different vendors and will be evaluated for cost effectiveness.

# MoDOT's Lidar Efforts

- MoDOT Photogrammetry unit has entered into a contract for aerial LiDAR surveys in the 2011 flight program for four projects consisting of 85.2 miles for new or realigned roadways. These projects are a mix of both urban and rural terrain and are ones that would have been done by traditional photogrammetric methods. Aerial photography is also being obtained on these projects as a means of quality control.

# MoDOT’s Lidar Efforts

- MoDOT is participating in, and has a member on the panel for NCHRP Project 15-44, Guidelines for the Use of Mobile LiDAR in Transportation Applications. This project is setting nationwide standards for the procurement, accuracy levels, and delivery methods of mobile LIDAR.

# MoDOT’s Lidar Efforts

- MoDOT also has a member on a TRB Committee on Geospatial Data Acquisition Technologies in Design and Construction, AFB80. This group evaluates data acquisition technologies, such as LiDAR, and makes recommendations for methods and procedures in these areas.  When results of this committee are published, MoDOT intends to use these results to write specification for future Lidar work.

# Aerial LiDAR

- County and statewide aerial LiDAR acquisition available through MSDIS (Missouri Spatial Data Information Service) could be used for:
  - Hydraulic Analysis.
  - Environmental Analysis and Mitigation Design.
  - Historic Preservation Analysis.
  - Project Scoping/Preliminary Design.

# Aerial LiDAR

- Increase the accuracy of corridor mapping for developing proposed 3-dimensional highway and bridge design models.
- Engineering accuracy 3D-models that can be used for rendering and making visual aids for the public at no extra cost to MoDOT.
- 3D models of proposed projects will have engineering grade accuracy for better estimates.
  - Better calculation of earthwork using volumetric differences.
  - Better calculation of pavement and other surfaces .

# Mobile LiDAR Potential Use

- Modeling large rehabilitation projects. Other DOT's are seeing great savings in pavement quantities for very large projects even with the cost of the acquisition of Mobile LiDAR.
- Emergency corridor mapping.
- Urban corridor mapping.
  - Can be used in high traffic areas where survey crews would have to collect data to supplement aerial LiDAR.
- Transportation Asset Management.  This task does not require high engineering accuracy.

# Terrestrial LiDAR Scanning

- Best for small improvement projects.
  - Isolated intersection improvement.
  - Land slide and side slopes evaluation.
  - Bridge inspection and evaluation – especially in high traffic urban areas.
  - Retaining wall and other structure monitoring.

Questions?